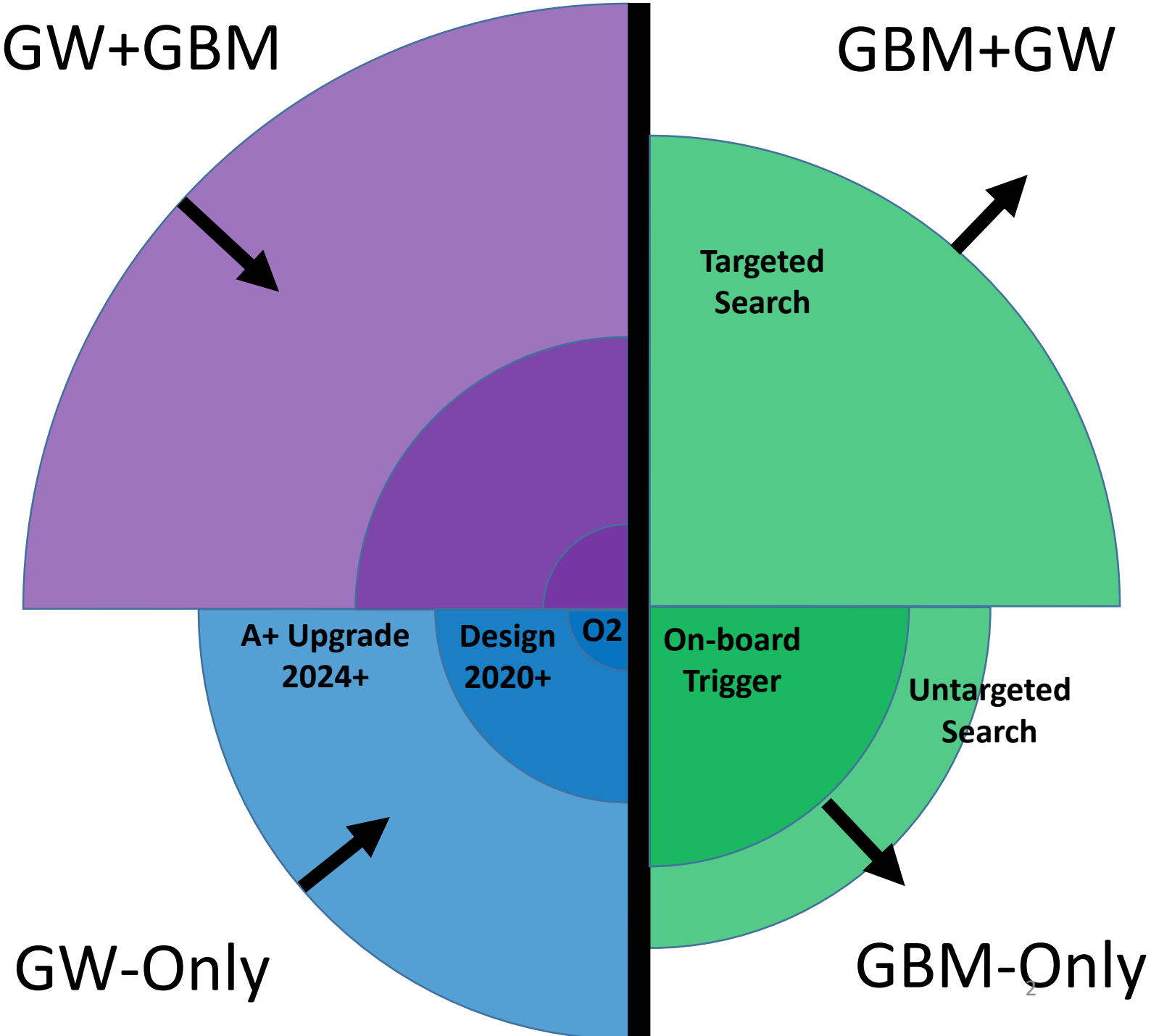
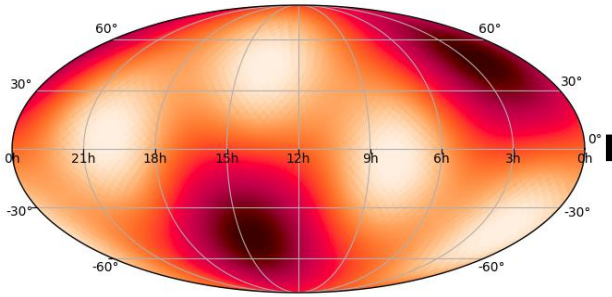
Joint LIGO/Virgo+Fermi-GBM Reporting

Why Joint Report?



Why Joint Report?

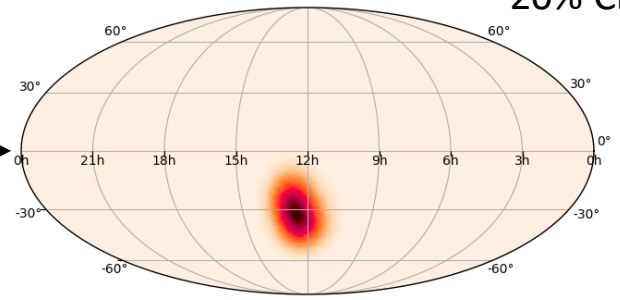
Single Interferometer GW Detection



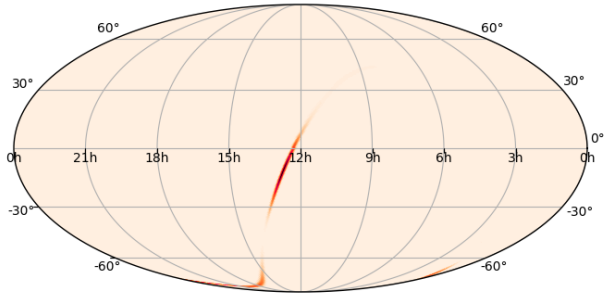
90% Reduction

Single GW + GBM Detection

~20% Chance



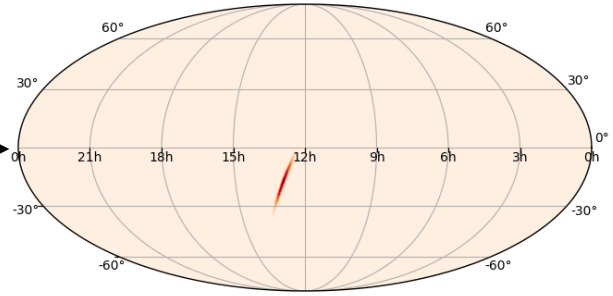
Double Interferometer GW Detection

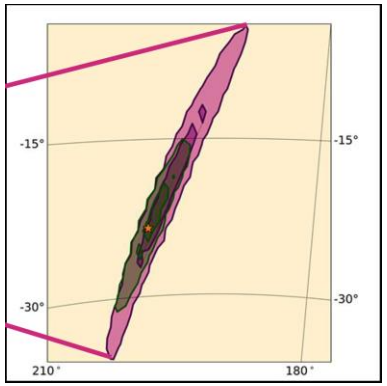


80% Reduction

Double GW + GBM Detection

~45% Chance





LIGO GW170817 +
GBM GRB 170817A
LIGO+Virgo GW170817

Rough Rates

- 0.3-1.7 joint detections for GBM on-board triggers with independent GW detections at Advanced LIGO design sensitivity

	O3		Design		
Joint Triggers:	0.10	1.40	0.30	1.70	From LIGO/Virgo, GBM, INTEGRAL GW-GRB paper
Untargeted SGRBs:	0.10	1.40	0.30	1.70	Assume all SGRBs equally likely to be nearby (Burns et al. 2016); assume only 40 SGRB candidates/year are real
Single IFO confirmation:	0.09	1.20	0.26	1.46	70% livetime for each GW intereferometer. Single IFO confirmation for 2*0.7*0.3 (over 0.7^2)
Joint search trials reduction:	0.07	1.02	0.22	1.24	20% trials reduction/SNR threshold reduction (Williamson et al. 2014, Blackburn et al. 2015), cubed for volume
Total:	0.36	5.02	**1.08**	**6.09**	Conservative estimate (ignores Virgo, the GBM Targeted search, and a low estimate of SGRB candidates as real)

- Ends up ~1-6 joint detections per year with sub-threshold signals
  - ~1-5 where the GBM localization information is important

LIGO/Virgo Triggers

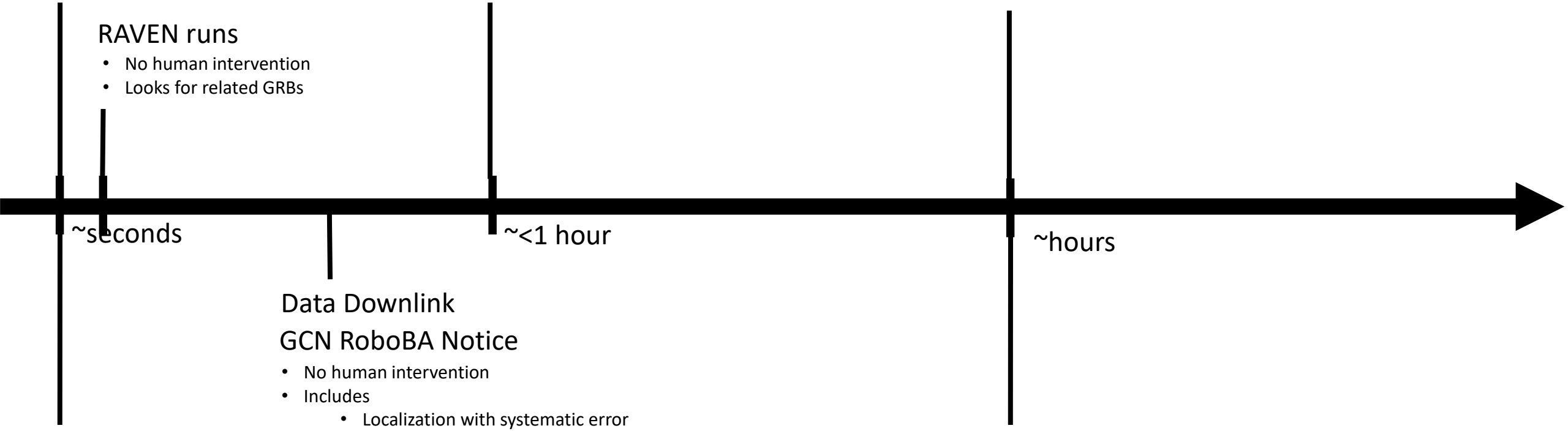
GCN Preliminary Notices
- No human intervention
- Several notices can be sent
- Information included as it is available

GCN Initial Notices
- Human involved

GCN Initial Circular
- Human involved

GCN Update Notices
- Human involved
- E.g. update skymap information

GCN Update Circular
- Human confirmation



Fermi-GBM Triggers

Guiding Principles

- Make this easy for the follow-up community to use
- Attempt to minimize false associations in automatic reporting
  - Stringent thresholds for fully automatic reporting
  - Human confirmation otherwise
- Design it to be applicable beyond just Fermi-GBM
  - Future joint GW-GRB reporting method
- Do this without introducing latency to the LVC reporting

Proposal: Joint Triggers, Preliminary Notices

- LVC preliminary notices go out as usual
- Once RAVEN runs, if there is an associated GRB
  - Determine GRB_Joint_FAR
  - If threshold is met – automatically distribute joint information
    - Threshold either I_omega, or on GRB_Joint_FAR

```
TITLE:            GCN/LVC NOTICE
NOTICE_DATE:      Wed 23 Aug 17 13:33:50 UT
NOTICE_TYPE:      LVC Preliminary
TRIGGER_NUM:      G298936
TRIGGER_DATE:     17988 TJD;   235 DOY;   2017/08/23 (yyyy/mm/dd)
TRIGGER_TIME:     47638.517903 SOD {13:13:58.517903} UT
SEQUENCE_NUM:     1
GROUP_TYPE:       1 = CBC
SEARCH_TYPE:      0 = undefined
PIPELINE_TYPE:    4 = GSTLAL
FAR:              1.739e-11 [Hz]  (one per 665711.8 days)
```

GRB_Joint_FAR: Value calculated by RAVEN, Michal's work

```
TRIGGER_ID:       0x0
MISC:             0x1100003
```

SKYMAP_URL: graced link to bayestar.fits.gz file

SKYMAP_GW_URL: graced link to bayestar.fits.gz file

```
EVENT_URL:        https://gracedb.ligo.org/events/G298936
COMMENTS:         LVC Trigger Alert.
COMMENTS:         LIGO-Hanford Observatory contributed to this candidate event.
COMMENTS:         LIGO-Livingston Observatory contributed to this candidate event.
```

COMMENTS: GBM Trigger Alert – YYMMDDxxx / MET

COMMENTS: Fermi-GBM contributed to this candidate event

Defaults to GW-only skymap. If GW+GRB detection then this is the joint skymap

Proposal: Joint Triggers, Initial Notices

- If there is a joint detection LVC+GBM join in TeamSpeak
- LVC handles their end. GBM POC signs off on if the event is consistent with a SGRB origin or not
- If both sides confirm events are real and likely related:
  - The LVC will send the GCN Initial Notice with GBM information
- If no GBM person is available and the event is reliably classified as a GRB, the LVC can do this
  - Necessary to ensure we don't delay announcements during the first hour

```
TITLE:            GCN/LVC NOTICE
NOTICE_DATE:      Wed 23 Aug 17 13:36:13 UT
NOTICE_TYPE:      LVC Initial Skymap
TRIGGER_NUM:      G298936
TRIGGER_DATE:     17988 TJD;   235 DOY;   2017/08/23 (yyyy/mm/dd)
TRIGGER_TIME:     47638.517903 SOD {13:13:58.517903} UT
SEQUENCE_NUM:     2
GROUP_TYPE:       1 = CBC
SEARCH_TYPE:      0 = undefined
PIPELINE_TYPE:    4 = GSTLAL
FAR:              1.739e-11 [Hz]  (one per 665711.8 days)
PROB_NS:          0.00 [range is 0.0-1.0]
PROB_REMNANT:     0.00 [range is 0.0-1.0]
```

GRB_Joint_FAR: Value calculated by RAVEN, Michal's work

```
TRIGGER_ID:       0x8
MISC:             0x2100203
```

SKYMAP_URL: graced link to bayestar.fits.gz file

SKYMAP_GW_URL: graced link to bayestar.fits.gz file

Defaults to GW-only skymap. If GW+GRB detection then this is the joint skymap

```
COMMENTS:         LVC Initial Skymap -- a location probability map.
COMMENTS:         This event has been vetted by a human.
COMMENTS:         LIGO-Hanford Observatory contributed to this candidate event.
COMMENTS:         LIGO-Livingston Observatory contributed to this candidate event.
```

COMMENTS: GBM Trigger Alert – YYMMDDxxx / MET

COMMENTS: Fermi-GBM contributed to this candidate event

Proposal: Joint Triggers, Initial Circular

- All Initial, Update LVC GCN Notices are accompanied by human-written circulars
- The initial circular is the announcement circular
  - Basically what the LVC distributed for the LV+EM O1/O2 partners
- This circular would be written on behalf of both collaborations
  - We will come up with GCN circular templates ahead of time

- If no GBM person is available and the event is reliably classified as a GRB, the LVC can do this
  - Necessary to ensure we don't delay announcements during the first hour

Proposal: Joint Triggers, Update Notices

```
TITLE:            GCN/LVC NOTICE
NOTICE_DATE:      Tue 29 Aug 17 20:34:37 U
NOTICE_TYPE:      LVC Update Skymap
TRIGGER_NUM:      G298936
TRIGGER_DATE:     17988 TJD;   235 DOY;   2017/08/23 (yyyy/mm/dd)
TRIGGER_TIME:     47638.517903 SOD {13:13:58.517903} UT
SEQUENCE_NUM:     6
GROUP_TYPE:       1 = CBC
SEARCH_TYPE:      0 = undefined
PIPELINE_TYPE:    4 = GSTLAL
FAR:              1.739e-11 [Hz]  (one per 665711.8 days)
PROB_NS:          0.00 [range is 0.0-1.0]
PROB_REMNANT:     0.00 [range is 0.0-1.0]
```

GRB_Joint_FAR: Value calculated by RAVEN, Michal's work

```
TRIGGER_ID:       0x8
MISC:             0x6100203
```

SKYMAP_URL: graced link to bayestar.fits.gz file

SKYMAP_GW_URL: graced link to bayestar.fits.gz file

```
COMMENTS:         LVC Updated Skymap -- a location probability map.
COMMENTS:         This event has been vetted by a human.
COMMENTS:         LIGO-Hanford Observatory contributed to this candidate event.
COMMENTS:         LIGO-Livingston Observatory contributed to this candidate event.
```

COMMENTS: GBM Trigger Alert – YYMMDDxxx / MET

COMMENTS: Fermi-GBM contributed to this candidate event

- The LVC Update Notices would carry the same additional information as the Preliminary and Initial Notices
- The LVC would send these updates as they normally would (e.g. better skymaps)
- Fermi-GBM could provide improved skymaps as this time, but the LVC would send the alerts

Defaults to GW-only skymap. If GW+GRB detection then this is the joint skymap

Proposal: Joint Triggers, Update Circular

- All Initial, Update LVC GCN Notices are accompanied by human-written circulars. This circular would be written on behalf of both collaborations
  - We will come up with GCN circular templates ahead of time

Proposal: Dependent Events

- LVC Dependent Events:
  - These include single interferometer triggers and GW triggers from the LVC GRB follow-up pipelines
  - Such events with associated GBM triggers would enter at the ‘GCN Initial Notice’ (human confirmation) stage, and proceed through the rest of the stages the same

- Fermi-GBM Sub-threshold Events:
  - The GBM Untargeted SGRB search produces SGRB candidates on its own. The GBM Targeted Search is seeded with GW information (analogous to LVC GRB searches). These both take 2-6 hours before reporting due to data downlink delay
  - ***Only medium or high reliability SGRB candidates should enter in GraceDB, as this could be automatically associated to a GW trigger***
  - Events of interest from these would likely enter at the ‘GCN Update Notice’ stage and proceed accordingly

- For less confident associations (or non-GraceDB events):
  - Send out a joint GCN Circular that describes the events and contains a link to the joint skymap. Observers can use their judgement here

To dos:

- Determine the automatic reporting thresholds – Michal+(?)
- Determine which GRB untargeted SGRB candidates are automatically placed into GraceDB – Karelle(?)
- Draft circular templates – Eric, Mina+(?)
- Additional GBM Information:
  - GRB classification percentage
  - Use of the GRB ‘likely a SGRB’ flag? (~85% accurate)
- Build a ‘kill switch’ for times when GBM has bright flaring sources